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SYMPOSIUM ON THE THEORY OF RELAY DEVICES AND  
FINITE AUTOMATA

-USSR-

[Following is the translation of an article  
by M.A. Gavrilov (Doctor of Technical Sciences)  
in the Russian-language publication Vestnik  
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USSR), No 4, April 1963, pages 85-88.]

One of the basic and intensively developing branches of technical cybernetics is the theory of relay devices and finite automata which serves as a basis for the construction of complex automatic control systems using discrete methods. Relay devices and finite automata are good dimulators of the logical operations performed by man, and with the growing complexity of the problems of automatic control and the development of logical functions within them, the significance of the theory of such devices continues to increase. This explains the great interest shown in the development of this theory by broad circles of engineers and scientific workers both in the USSR and abroad.

In accordance with the resolution of the First Congress of the International Federation on Automatic Control (IFAC) in Moscow on 29 September-2 October 1962, a symposium was held on the theory of relay devices and finite automata which included Soviet scientists, foreign delegates, and guests from 15 countries.

At the plenary meetings and in the five sections (on abstract automata theory; probability automata, signal construction theory, and reliability theory; relay structure design methods; minimization of Boole functions and bridge structure synthesis; mechanization of synthesis and analysis functions) the foreign delegates presented 28 papers, while 22 papers and 24 brief reports were delivered by Soviet specialists. The introductory survey was presented by the author of the present article.

A characteristic feature of the present stage in the development of the theory of relay devices and finite automata is the consideration of a number of general fundamental problems involved in their design. Among these, for example, are the problem of "representability" which in general form concerns the question of which functions can in principle be fulfilled by discrete devices; the problem of "realization" dealing in general form with the question of the necessary extent of technical means for the realization of specific functions fulfilled by the relay device; the "quick-response" problem concerned with the question of minimum lag in the response of the relay device to external inputs and the relationship between the value of this lag and the extent of necessary technical means, etc. A considerable portion of the papers at the symposium dealt with precisely these questions.

Modern relay device and finite automata theory can be broken down into two parts: the abstract theory where the device is considered as a combination of some finite number of abstract relay elements (cells, abstract neurons, etc.) characterized solely by the number of states these assume (without any regard for the structural properties of the elements as such), and the structural theory which is concerned with the problem of realizing the structure of relay devices with due regard for the structural properties of the relay elements of which they consist.

The problems of abstract theory were discussed in two sections (abstract automata theory; probability automata, signal construction theory, and reliability theory). The papers presented contained a number of essentially new formulations. These included a generalization of the theory of relay devices and finite automata and the theory of digital computers through the consideration of the latter as a class of finite automata (V.M. Glushkov, USSR; L. Kalmar, Hungary). A.N. Kolmogorov (USSR) examined the character of the dependence between general evaluations of complexity and quick response for finite automata. G.K. Moisil surveyed work being done in Rumania on the theory of relay device construction using noncontact components. The paper of A. Berkes (US) contained a proposal for a theory of "block" automata taking into account the signal transfer time between individual blocks and limitation of the placement of relay elements and connections characteristic for a number of modern noncontact relay elements.

A number of papers by Soviet researchers dealt with the problem of a "language" for the symbolic recording of operating conditions and performance of synthesis operations, as well as problems of the composition of automata (construction of complex automata from simpler ones).

There were discussions of the problems involved in the study of "asynchronous" automata and the evaluation of the complexity of the realization of finite automata under specific conditions.

Papers by scientists from various countries were concerned with minimization of the number of states; some special methods for the solution of this problem were presented as refinements of existing ones.

It is necessary to note the almost total absence of papers on the problem of the so-called "distribution" of states which as yet has not received sufficient treatment in modern relay device theory. Only two papers contained a consideration of certain special aspects of this problem.

The great interest evinced in papers dealing with the problems of reliability and coding is explained by their ever-increasing importance in connection with the increasing complexity of functions executed by relay devices and the complexity of the devices themselves. Here it is possible to distinguish the most essential trends: the solution of the problem of the theoretically possible maximum of reliability in the realization of the specified functions; the determination of the minimal complexity of relay device realization capable of assuring required performance reliability; the determination of the complexity of the means of control for the timely detection of failures or their prediction; the operation of relay devices in random media (i.e., in the presence of signals of a probabilistic character), including devices with an adaptive structure. The survey report on the problems of assuring relay device reliability through increased informational and structural margins was delivered by G. Glinski (Canada). A number of papers dealt with the special problems of reliability analysis and optimal methods of failure search. L. Lefgren (Sweden) considered the problems of self-restoration of relay devices following errors and the required margins.

The problems of coding were considered in just two reports by M. Cohn (US) and R.R. Varashamov and V.M. Ostianu (USSR). The latter contained an interesting formulation consisting in the use of finite field theory for the determination of the list of nonintersecting state sets.

Three papers by Soviet scientists dealt with the synthesis of automata adaptive to external inputs. Consideration was given to the problems of the expedient behavior of automata in finite media, including variable-structure automata.

Certain new trends became apparent in the consideration of structural theory problems in the sections on relay structure design methods, Boole function minimization, and the synthesis of bridge structures. One new contribution was a more general for-

mulation of a certain problem, namely: a departure from the consideration of problems involved in the synthesis of structures using specific concrete components having narrow structural properties, and a transition to the solution of problems of minimal structure synthesis with a selection of a minimum number of relay elements, or the solution of the minimization problem for relay elements with complex structural properties. Such a general formulation of the problem was contained in the papers of L. Lefgren (Sweden), and D. Roth, B. Dunham and D. North, R. Karp (US). The paper by Yu.V. Kapitonova and Z.Ya. Rabinovich (USSR) contained a description of studies by the Cybernetics Institute of the Academy of Sciences Ukrainian SSR directed toward the synthesis of the structure of a relay device (whose operating conditions are given by a system of Boole functions) from elements with specified logical properties, delay times and weight, which is a function of cost, dimensions, durability, etc.

One of the types of relay elements possessing complex structural properties are the so-called "threshold" components. The synthesis of structures using these components was discussed in the papers of I.M. Bogolyubov (USSR) and L. Dadda (Italy). A number of papers was devoted to the very timely question of the synthesis of relay device structures employing diodes. The most interesting of these was the paper by V.V. Obraztsov describing a method of constructing diode networks with dipole linkage which provides a considerable saving in diodes and resistors. Few methods for minimizing Boole functions and synthesizing bridge structures were described in papers by scientists of various countries. Of great interest was the paper by R. Peter (Hungary) on the definition of the "main" operation in the construction of bracketed forms of Boolean functions.

In other papers, attention was concentrated on the problems of eliminating competitions in executive circuits, the algebra of relay chains with polarized and tripole components, and the transition from switching tables to structural formulas.

One of the most important problems of the practical application of the theory of relay devices is the mechanization of synthesis processes. The fact is that the unwieldiness of the synthesis operations rises rapidly with the number of variables. Even the best methods of synthesis applicable in the solution of the most complex problems, allow for not more than five or six variables with manual computation, while in practical problems of relay technique, the number of variables may reach 30-40.

Efforts on mechanization began just 3-4 years ago. Now we see three basic trends in this field: the creation of specialized computers for the solution of individual synthesis stages; the creation of logical attachments for the solution of synthesis problems on universal computers; the programming of synthesis problems on such computers.

Efforts on the creation of specialized machines for synthesis are going on mainly in the USSR, where machines have been constructed for the analysis of relay structures and Boolean function minimization. Such a machine was described in the paper of B.L. Timofeyev (USSR). The mechanization of the determination of switching table realizability was the subject of a report by E. Bromirski (Poland).

The second trend, likewise being successfully pursued in the USSR, found treatment in the papers of the staff members of the Siberian Physico-Technical Institute (Tomsk). The principles of the construction of a logical attachment, as well as methods of solution of synthesis problems with its aid, were considered.

Of the papers on the problems of synthesis problems programming on universal computers, it is necessary to mention the report by A.A. Stogniy (USSR) on the work of the Cybernetics Institute of the Academy of Sciences USSR on the creation of an algorithmic system for the mechanization of all stages of synthesis, starting with the conditions of operation of the relay device recorded in the "regular events" language, and ending with the logical scheme of the relay device structure. The great complexity of solving synthesis problems was noted. For example, a universal computer with a speed of 10 thousand operations per second, with an operational memory of 2-4 thousand words and an external memory of several tens of thousands of words, is applicable for the synthesis of relay devices with a product of the number of letters in the input alphabet by the number of states not exceeding 16 thousand. The synthesis of a relay device realizing 4 functions of 10 variables takes up about an hour of machine time on such a computer.

A number of problems in the minimization of test programs was considered in the paper by I.V. Kogan (USSR).

In conclusion it is necessary to note the scientific value of the symposium which contributed considerably to advancing the modern theory of relay devices and finite automata and served to indicate the timeliest trends of its further development.